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CONTROLLING RICE LOSSES TO RODENTS IN RURAL COMMUNITIES

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Numerous species of rodents have long been recognized to have detrimental effects on human health, quality of life, and food production. Rodent problems are found throughout the world, in all types of environments - - from cities to subsistence farms. At least 20 different species of rodents may be considered important pests of agricultural crops in the tropics and subtropics (Fall 1980). While methods, materials, ad a variety of service delivery systems to reduce the impact of the three commensal species have been available in temperate urban areas for many years, concern with rodent problems on small farms in developing countries has been a more recent phenomenon. Efforts to increase food production and to identify and treat tropical diseases in the post-war development era brought increased attention to rodent problems in agricultural areas in the tropics. Increased support for research led to rapid growth of the technical literature of rodent control. According to Kaukeinen's 1987 compilation, the worldwide rate of publication of technical papers related to rodent control increased from about 400 papers per year in the 1950's to about 1200 per year in the mid 70's; current rates are substantially higher.

Considerable effort was also devoted, particularly during the mid - 1970's early 1980's, to development of pilot operational rodent control programs, to training of agricultural technicians in rodent control techniques, and to marketing of commercial materials for rodent control on small farms. Despite this growth of activity during the past 2 or 3 decades, small farms, rural households, and villages continue to suffer devastating crop and storage losses and the need for periodic emergency programs to offset the effects of rodent population outbreaks remains common. Rodent-borne diseases continue to be a serious public health problem in many areas of the world (Gratz 1988). Even on agricultural experiment stations, where much of the leadership for development and application of agricultural technology resides, rodent damage to research plots and stored materials continues to be serious problem (Ahmed et al. 1987). Why have these losses continued? What has limited the successful application of rodent control technology to the world's small farms and villages? What has been missed in devising control programs and providing information and materials to farmers and rural villagers? What questions are important for scientists to address? This paper, following the outline and terminology proposed by Fall (1980), will be briefly explore some of the potential strategies, techniques, implementation factors, and constraints for developing programs to reduce preharvest and postharvest rodent damage on small farms in rice-based agriculture.

SMALL HOLDER ECOSYSTEMS

More than 90% of all tropical farms are less than 5 hectares in size, averaging in some countries between 1 and 2 hectares (Harwood 1979). Throughout much of the world, the mixed farm with small plots of a variety of crops, a few animals, a few fruit trees, and on-farm storage of produce is a major source of food for the peoples of developing nations. In many areas, particularly in rice-based agriculture, groups of farmers may plant rice or other field crops in large monoculture blocks separated from dwellings, gardens, or village areas. Richards and Buckle (1987) termed these complexes of fields and dwellings the "small holder ecosystem". Typically, such farms in the tropics and subtropics maintain many small plots of variety of crops with planting and harvesting occurring through much of the year. Because domestic animals, pets, and children are active in these areas, the hazards of using toxicants may be greater than in large fields of a

single crop. When portions of the farm area are not contiguous, or when fields are part of monoculture blocks away from dwellings, the problem of rodent control becomes more complex and difficult for a small holder to manage alone. Although the pest rodent species may vary in different parts of the world, usually the same species or group of species living on the farm damage a number of crops at different growth stages, infest dwellings and other farm structures, consume or contaminate locally stored produce, and carry disease organisms that may infect humans and farm animals. During rodent population outbreaks, the harborage and food available on farms may result in movements of substantial numbers of additional rodents from outside the farm area, particularly during dry periods. Similarly, during harvest periods, a pattern of rodent movement into villages, homes, or off-season crops is common. Because rodents may impact so many aspects of rural life, control of rodent damage should, ideally, be organized around managing this small holder ecosystem rather than protecting particular crops or commodities.

Brown (1970) expected improvements in programs for reducing rodent losses in developing countries based on increasing interest and support by international agencies, national governments, and private foundations. Indeed, with this support, substantial progress was made in developing effective rodent control methods and programs for a number of specific crop damage problems including rice (Wood 1971; Schaefer 1975; Fall 1977; Dubock 1982, 1984), sugarcane (Hilton et al. 1972), oil palm (Wood 1969), coconut (Fiedler et al. 1982), maize (Sanchez et al. 1975), wheat (Anon. 1982), and vegetables (Advani and Mathur 1982), among many others. Parallel efforts during this period were focused on methods and programs to manage post-harvest losses caused by rodents in homes, villages, or grain storage facilities (Lindblad and Druben 1976, Howard et al. 1979; Bullard and Schuyler 1983). Most of these methods have relied upon the effective use of rodenticides.

Many of these recent efforts to develop rodent control techniques and programs have had the goal of reducing damage by one particular rodent species under a narrowly defined set of monocultural crop or storage conditions in a particular country. Such approaches have related in part to the nature of the pest situations and external program support and in part to the experimental convenience of designing studies on uniform areas with a single crop. Considerable work remains to adapt these various control techniques and programs to other situations involving the same monoculture crops damaged by different rodent species under different ecological or cultural conditions (Fall 1982; Elias and Fall 1988). Nonetheless, current technology permits a broader approach to agricultural rodent control; Madsen (1975), Prakash (1975), Richards (1986), Richards and Buckle (1987) have described efforts to manage the small holder ecosystem as a unit.

The lack of reliable estimates of worldwide economic losses caused by rodents may be one of the constraints to development of better coordinated rodent control efforts (Sanchez 1975). Hopf et al. (1976) attempted to obtain such information by mail survey and Jackson (1977) reviewed more than 100 published studies of crop and storage losses to rodents. According to Jackson's analysis most estimates of losses are statistically unreliable and the magnitude of worldwide losses, though substantial, is open to guess. Such "guesses" in the popular press and some technical accounts are extraordinarily high; in the professional literature rodent losses are generally combined with the overall estimates for damage from all pests (Pimentel 1978). "Average" losses are undoubtedly much lower than the figures typically cited; however, data from field experiments in rice have generally indicated that substantial increases yield can be obtained when effective rodent control is practiced. However, average losses have little meaning for producers who must contend with a variety of constraints to successful production and storage. The variable and unpredictable occurrence of heavy rodent damage is also a risk factor from the producer's standpoint and may influence decisions to begin new farming practices, grow new crops or varieties, or obtain loans to finance essential materials and techniques to increase production (Fall 1982). While loss estimates for many agricultural pests can readily determined from small plots, the large activity ranges of most rodents, their adaptability to a variety of habitats,

their opportunistic food habits, and their longer life cycles compared to many invertebrates make such projections difficult. The economic impact of food contamination and disease transmission is even more difficult to determine and is usually ignored in economic impact estimates, yet public health is often identified as an important reason for local or national government concern for improved rodent control.

STRATEGIES

Much has been accomplished since Brown's (1970) examination of rodent damage problems. However, renewed efforts are now clearly needed to identify strategies suitable for integrated rodent control for the farm/home/village complex. Self-sustaining systems must be organized to make essential information and materials available to the farmers and villagers who must be the key participants in successfully reducing rodent damage.

Tolerance has, perhaps, been the overriding strategy used by farmers in dealing with rodent problems. In the past, this was practiced by increasing the area planted to compensate for pest damage. Nonetheless, rural peoples worldwide are highly aware of rodents and rodent damage; folklore is replete with stories about how to contend with rodent problems. In general, when rodent control activities are undertaken by farmers, they are simple, low-cost, often ineffectively applied techniques such as constructing rodent guards for houses or storage structures, keeping cats or dogs, organizing rat drives in fallow fields or nearby rough areas, token baiting with small amounts of rodenticide, or trapping, often with a single trap. The focus is nearly always on visible rodents than on crop damage which is often hard to detect during the growing period.

Periodic rodent control campaigns are sometimes attempted under government or external donor sponsorship. Intermittent campaigns are difficult to manage and are rarely successful in reducing damage, even though large numbers of rodents may be killed. Rodent populations quickly rebuild by immigration and reproduction, particularly in tropical or subtropical areas where food and cover may be abundant in non-crop areas. Often, campaigns are focused on monocultures and may not reach the farmer planting a variety of crops or deal with post-harvest losses. As production improvements and better availability of markets make farms a source of income in addition to family subsistence, the incentives for farmers to protect crops and storage from rodent damage as a routine part of production efforts increase.

Other general strategies for dealing with rodent problems include eradication, population reduction, exclusion of animals from areas of concern, or making environments unsuitable for rodent habitation. All of these, as single strategies, present problems or impossibilities in many tropical agriculture situations; integrated management approaches focused on specific program objectives that incorporate surveillance and monitoring are clearly the preferred strategy for the rodent problems encountered in the small holder ecosystem. Careful choice of objective(s) is essential, but the key to a management program is to devise effective ways to provide feedback on its performance. Counting dead rats, a common practice in many control efforts, is not a good way to determine the effectiveness of a program aimed at reducing crop damage; better monitoring techniques are clearly needed. Insofar as the problems encountered in the different parts of this ecosystem differ in terms of species, time, habitat, and potential hazards, effective management strategies may necessarily be complex and compartmentalized, having more than one objective.

Integrated pest management (IPM) approaches have indeed been applied to many rodent damage problems, particularly those involving a single species in a single crop. Simply defined, IPM entails broad, ecologically based control systems that use and manipulate multiple plant protection tactics in an effective and coordinated way (Smith and Calvert 1978). Unfortunately, IPM is sometimes interpreted as an alternative to pesticide use that must focus on the

microeconomics of particular crops. Marsh (1981) among others has cautioned the need to devise IPM programs for vertebrate control without blindly accepting the parameters and principles developed for invertebrate pests which are in many cases inappropriate. The challenge, as identified by Richards and Buckle (1987), is to devise management programs that take account of all components and constraints in the ecosystem where rodents must be managed. Such programs must be devised to allow effective rodent damage control to become a routine part of agricultural production and of improving the quality of life in rural homes and villages. For this to happen, both information and appropriate, affordable materials must be readily available.

TECHNIQUES

Many methods for rodent control (Table 1) have been suggested, tested, or used in attempts to manage rodents or rodent damage. Only a few have been objectively evaluated for control of rodent damage to rice and some may be ineffective. Some methods may be hazardous to the health and safety of humans or domestic animals or have unacceptable impacts on wildlife or the environment. Reasonable effectiveness in preventing or reducing damage is, of course, a principal consideration in identifying appropriate control methods. In many situations where little is known about pest species, evaluation of candidate techniques or combinations of them would be necessary before making detailed recommendations. Small-farm economics, among other factors, would greatly limit the variety of management techniques the might be appropriate for rice-based agricultural problems. Techniques requiring a large capital investment; for example, constructing pest-proof storage buildings, might be ruled out for many situations simply because of insufficient farmer capital. Some additional considerations in selecting and evaluating techniques are safety for humans, farm animals, and nontarget wildlife; practicality in relation to other farm activities; short-term or long-term environmental side effects; and cultural acceptability to farmers and villagers. Drummond (1977) and many others have long contended that existing techniques are sufficient to develop integrated control programs and that pilot demonstration projects are urgently needed to introduce technology and guide further research. Nonetheless, much of the research literature on rodent control continues to focus on devising, evaluating, modifying, and assessing the environmental hazards of particular techniques and materials - - with emphasis on baits and rodenticides. Relatively little effort on IPM approaches - - integrating of control methods, relating their use to intensity of damage, or monitoring their effectiveness - - is reflected in the technical literature.

Table 1. Methods and techniques for rodent control that have been suggested, tested, or used for various rodent problems. Only few of these methods have been objectively evaluated for control of rodent damage to rice and some may be ineffective. Some may be hazardous to the health and safety of humans or domestic animals or have unacceptable impacts on wildlife or the environment.[1]

Physical	Chemical	Biological	Other
Rodent proof construction	Baits/baiting systems	Harborage removal	Appeasement
Barriers:			
Passive,electric	Poison sprays	Habitat modification	Bounties
Drift fences	Poison moats	Cultural practices	Harvest
Trapping	Tracking powder	Crop timing	Compensation
Flooding burrows	Tracking greases, gel	Crop diversification	Insurance
Drives	Repellents	Buffer crops	
Hunting	Attractants	Parasites	
Clubbing	Aversive agents	Diseases	
Frightening devices	Plant systematics	Predators	
Flame throwers	Sterilants	Ultrasonics	
Burrow destruction	Fumigation	Biosonics	
Habitat destruction	Psychotropic drugs	Resistant plants	
	Glues	Lethal genes	
		Immunogens	

[1] Modified from Fall, 1982

A variety of different rodenticide concentrates and bait formulations are available in most countries and efficacy data are available for a number of the most important rodent species that damage rice. Often, however, availability of such materials is very limited in rural areas because commercial marketing is frequently focused on urban households, in areas where plantation or export crops are prevalent, or on government plant protection programs. If programs utilizing rodenticides are to be organized, reliable local sources of supply for farmers and villagers are essential. In many countries, marketing of rodenticides in rural areas has been slow to develop, partially due to a political focus and materials are only available irregularly or in token amounts to farmers. Nonetheless, the possibility of government action provides a reason for farmers to delay their own efforts.

A major consideration in using rodenticides in small-farm programs is safety for farm families and domestic animals. Mixed farm situations, generally, provide much greater potential for accidental human or animal contact with these toxic materials than do the uses in single crops. Preformulating rodenticide baits with minimum toxicity, using chronic toxicants which act slowly and have antidotes, using tamper-resistant or concealed bait containers, educating families about pesticide safety, and penning animals during baiting periods are potential ways to reducing the hazards of accidental exposure. In many of the small farm areas of the world, the costs entailed and levels of extension activity necessary to meet such safety requirements are unlikely to be realistic outside subsidized programs or demonstration project.

Among the more simple techniques that might be evaluated as IPM program components for small holder ecosystems, several fall within the "removal or reduction of rodent harborage" category. Clearing debris, rock piles, weeds, and brush from fields or gardens and surrounding perimeters may, for some rodent species, be a way to reduce rodent activity within fields or yards; trimming or relocating trees or shrubs that provide paths to roofs, and minimizing the availability of

food scraps or spilled grain from drying operations can help reduce rodent activity and access. Restructuring fences with sticks or wire to prevent debris from collecting might make such situations less susceptible to rodent infestation. Likewise, placing harvested grains or other crops that must be temporarily stored or dried on racks may in some situations, prevent substantial damage. For large storage piles which cannot be raised from the ground, trenching around their perimeters may prevent or reduce rodent access. Preventing rodent access to structures often provides difficult in tropical areas because of the relatively open construction that is generally used; however, any building modification or repair that can reduce rodent access would be extremely useful. Using and maintaining rodent-proof storage containers within houses and placing stored material on racks or shelves off the floor, away from walls, may also be helpful.

Periodic trapping may be useful technique for maintaining low rat activity if populations are not too high, if area are limited in size,and if reinvasion of rodents from outside the farm area is relatively slow. Effective use of trapping programs, even on a very small scale, depends on educating farmers that the capture of a few animals is no indication of "success". However, costs may well be a major consideration for farmers in deciding to use traps because acquiring even a few commercial traps could entail substantial cash outlay. Design and local construction of simple, low-cost traps appropriate for local rodent species and their intensive use in small farm rodent control programs have not been fully explored. Pit traps may be effective for some rodent species and need further evaluation. Traps would need to be used with sufficient intensity to maintain low rodent activity on the farm for sustained periods. Schuyler and Sun (1974) demonstrated that intensive trapping over a long period could form the basis for an effective rodent control program.

Barriers for protection of field crops, particularly rice, offer considerable promise for further development. For many years (Ramos 1969), lethal fences have been used to protect research plots from rodents at the International Rice Research Institute in the Philippines; variations have been devised by farmers, or copied at other facilities. With current technology, lethal electric barriers are expensive to install and maintain and have a number of drawbacks. These include high labor requirements, frequent grounding from weeds, rodents, or other small animals that hang on the wires; hazards to humans, livestock, and pets if operated continuously; and ineffective protection of plots if rodents gain access during periods when fields are dry or during periods when the fence is not in operation. Shumake et al. (1979) examined non-lethal electric fences that exclude rats but avoid some of the other problems and demonstrated a high level of protection for one-quarter hectare rice plots in two field trials. They calculated that costs per hectare would be comparable to the costs of baiting rodenticides if large areas could be fenced effectively. Reidinger et al. (1985) examined numerous additional design modifications for non-lethal electric fences and concluded that local materials (except for the fence charger) could be used effectively at substantially lower cost. An advantage of such non-lethal electric fences is that rats living near the barrier learn to avoid it, but servee themselves as a barrier to further rat invasion, interrupting the "sink" effect that occurs when small areas of attractive crops are available in the midst of abundant rat habitat. Lam (1988) showed that physical barriers combined with traps also have high potential for interrupting the massive influx of rats from surrounding areas to maturing ride fields.

IMPLEMENTATION FACTORS AND CONSTRAINTS

A variety of human and organizational factors are of equal importance with rodent biology and control methods in constructing, successful management programs. Each factor needs careful analysis in relation to the specific objectives of a program and may have important bearing on the types of control methods chosen. These factors include the management unit - - plants, fields, farms, or communities; the size of the area that must be encompassed; the operators - - individuals or organizations - - responsible for the program; critical periods for timing control operations; the means of supplying materials and labor; and the methods of surveillance,

monitoring, and assessment. Agricultural practices and social, cultural, legal, and environmental factors may constrain certain techniques or activities related to rodent control and must also be considered in devising appropriate programs. Because of great differences in countries and regions, evaluation of such factors is often of critical importance in adapting successful programs to new areas - - even if the crops and pest species are the same. Pilot projects or demonstrations provide an ideal way to evaluate such factors experimentally, but most such efforts miss opportunities to quantify social variables by focusing efforts on gaining program participation and by not using experimental controls.

Training and extension must also play key roles in developing sustainable crop or commodity protection programs. In many countries, only a small proportion of the agricultural extension personnel, much less farmers and villagers, have received even minimal training in the technical aspects of rodent control. In the Philippines, Dizon (1978) found that agricultural technicians were the principal source for farmers to obtain information about protecting rice from rodents and that inadequate training of technicians was a cause of slow progress in implementing effective rodent control. In areas where literacy rates are low, increased use of radio, films, videotapes, picture-stories, and posters may be effective means of maximizing extension contact. Identifying and using farmer information networks, training key farmers or group leaders, and establishing demonstration farms in rural areas are additional methods of organizing pest management extension programs with minimum personnel. Rural schools provide a means in many areas for frequent direct contact with children of small-farm families who are often involved at an early age in farm activities. Appropriate educational material prepared in major languages of instruction could be widely used in many countries to increase public awareness of rodent damage and means of prevention. Educating farm families about the impact of rodent damage is essential; implementing pest management programs and extending useful information will challenge the efforts and imaginations of available personnel in each country.

DISCUSSION

The ideas, techniques, and program approaches briefly outlined in this paper are not new to rodent control. Most have been utilized or proposed at one point or another in the various programs organized to reduce rodent damage to particular crops in post-harvest storage. However, the integration of such techniques in self-sustaining pest management programs presents a serious challenge. Estimates of economic loss will be much more difficult to obtain for small-farm units than for single crops. The research, adaptation, program evaluation, and extension processes may be more difficult due to the more diverse pest situations, safety considerations, and the necessity for developing effective implementation programs with minimal resources.

A key and unresolved question related to organizing management programs for rodent damage is how such programs should be "integrated". Rodent control as well as other vertebrate control efforts have often been handled, both in developed and developing countries, as special programs - - separately organized from other essential agricultural production, post-harvest, and public health activities. Often rodent control has been cast as possible only by large-scale community actions, requiring the services or oversight of specialists in government or the private sector. If this is so, the organizational task of bringing even rudimentary rodent control to a majority of the farms and villages in rice-based agriculture will be a long-term effort requiring extensive subsidy by national governments and perhaps external donors. If, alternatively, rodent control could be "integrated" as one of the essential activities necessary for a farmer to produce and store a successful crop, many of the problems discussed parallel those involving the introduction of other production and post-harvest technologies - - quality seeds, fertilizer, insect and weed control, small-scale farm machinery, drying and storage methods, and nutritional information. Such efforts generally have been focused on individual farm families and, in many cases, have been highly successful in achieving sustained use.

We are much better prepared - - both biologically and technically - - to develop integrated programs to manage rodent losses on small farms as a result of the considerable work in the past two decades to research, organize, and implement rodent control programs in developing countries. Unfortunately, the interest and substantial support from private foundations, international agencies, and national governments that developed in the late 1960's and inspired Brown's (1970) optimistic comments seriously declined in the 1980's, making the task of adapting, evaluating, and utilizing these findings that much more difficult. Nonetheless, the farmers are increasingly concerned with rodent damage and their farms must continue to produce food for a growing world population. With the resources available, we must continue the task of educating people, using existing information and materials in new ways , and devising more appropriate methods and programs to protect and conserve our food production and distribution systems from the losses and contamination caused by rodents.

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